Environmental Science Program at the Advanced Light Source

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Introduction

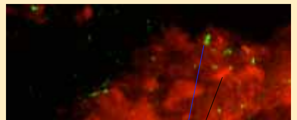
The Advanced Light Source (ALS) has a variety of capabilities that are applicable to very different types of environmental systems. Shown below are the basic descriptions of four of the approximately 35 beam lines at the ALS. The complimentary capabilities of these four beam lines allow for investigations that range from a spatial scale of a few nanometers to several millimeters. The Environmental Science Program at the Advanced Light Source seeks to promote and assist environmental research, particularly on the four beam lines described here. Several short examples of the types of research conducted on these beam lines are also described.

X-ray Microprobe (ALS Beam Line 10.3.2)

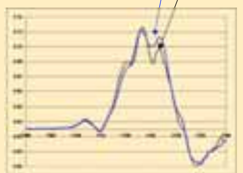
Beam Line 10.3.2 provides for the rapid collection of X-ray fluorescence maps and point X-ray absorption and powder diffraction data with <5μm spatial resolution.

Energy range from 2.5keV (Sulfur) to 17keV (Uranium)

X-ray Fluorescence Map showing the location of bacterial colonies within a soil slice. Iron is shown in Red, Bacteria shown in Green.



(Green is the Se fluorescence from CdSe quantum dots used to label the bacteria)

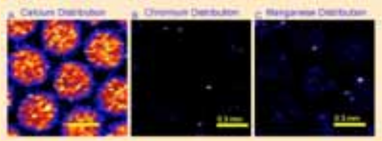


Iron XNES (1st derivative) on Iron underneath the indicated bacterial colony and away from the colony.

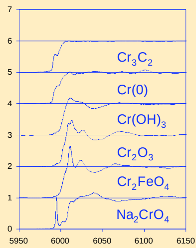
Karen Murray (Stanford University), Peter Nico (LBNL), Scott Fendorf (Stanford University)

What is the form of Cr in ambient atmospheric particulate matter (PM)?

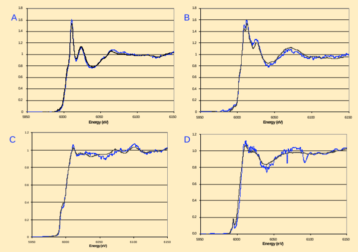
As a result of the very different toxicities of different forms of Cr, with Cr(VI) being highly toxic and Cr(III) being essentially non-toxic, the speciation of Cr within PM could have a dramatic effect of the toxicity of the PM.



XRF mapping showing the difference in Ca, Cr, and Mn distribution on a filter of PM2.5 collected in Sacramento, CA



XANES standards showing the difference in the spectra with Cr speciation



Spectra of individual Cr particles. Original data shown in dashed line and reconstructed spectra are shown in solid line. A: 100% "Fe/Cr Spinel" B: 100% Cr2O3 C: 36% Cr(OH)3, 64% Cr(0) D: 88% Cr(OH)3, 12% Cr(VI)

Location	Percentage Composition						
	Cr/Fe spinel	$Cr(OH)_3$	Cr_2O_3	Cr_2C_3	Cr (0)	Cr (VI)	Number of spots
Davis	61	18	11	0	9	0	18
Sacramento	36	42	7	1	12	2	27
Placerville	32	57	6	5	0	0	10

Average Composition of Particles from Different Sampling Locations

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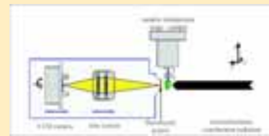
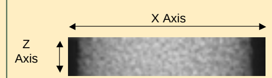
X-ray Micro-Tomography (ALS Beam Line 8.3.2)

Beamline 8.3.2 allows for collection of three dimensional images of solids with a few micron resolution.

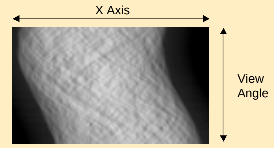
Experiment consists of illuminating the sample with a nominally parallel beam and recording a projection using a 2-D detector (CCD)

The 3-D optical density is reconstructed by calculation using fairly standard algorithms

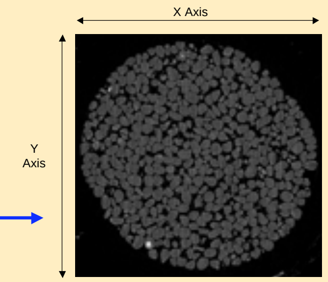


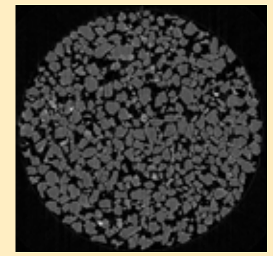


Single 2-D projection of sample optical density. Many such projection are taken at all angles in order to reproduce 3-D image



A one pixel (4.65 mm) thick slice of is taken from each projection at each angle sampled and stacked on top of one another to generate the sinogram





Sinogram is parallelized in order to generate a single 2-D slice of the sample

The final two images above show the effects of microbial activity on grain morphology and pore space. The two images are from columns packed with identical silica sand. The first image was taken as a baseline where as the second image is from a column that was inoculated with sulfate reducing bacteria and a solution of Fe(II) and sulfate. The sand grains from the second column show distinctly altered morphology as a result of the precipitation of a new dense phase, FeS. This new dense phase is seen here as lighter rinds around the original quartz grains.

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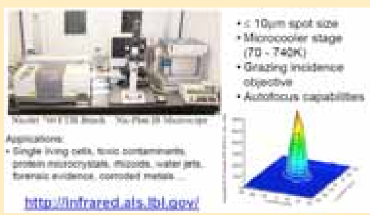
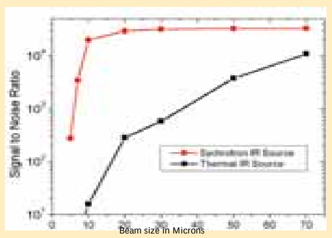
Synchrotron Fourier Transform Infared Spectroscopy (ALS Beam Line 1.4.3)



The use of a commercially available IR microscope makes beamline operations very user friendly.

It is well suited for direct monitoring of the effects of microbial metabolism because the IR light does not kill the cells.

The beam size is diffraction limited but averages around 10 microns depending on the wavelength range of interest.



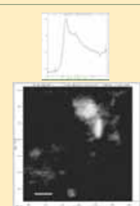
The advantage of synchrotron IR comes from the dramatically increased flux at lower spot sizes.

Scanning Transmission X-ray Microscope (STXM) (ALS Beam Line 11.0.2)

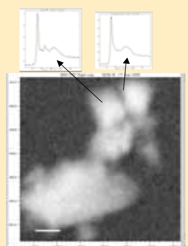
STXM can be used to obtain images with tens of nanometers resolution. By taking images of the same particle at difference X-ray energies absorption spectra (NEXAFS) can be obtained for given elements.

Beamline 11.0.2 also has a spectroscopy end station that can be used to obtain XPS spectra at ambient pressures as well as NEXAFS spectra of solids and solutions

Optical density map of a soil particle @ 800 eV. Scale bar 1 μm.



Map of Al in particle and spectra of Al. Scale bar, 0.5 μm



Map of Si in particle and spectra of two different types of Si in particle. Scale bar, 0.5 μm

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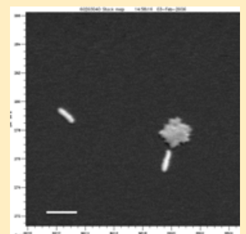
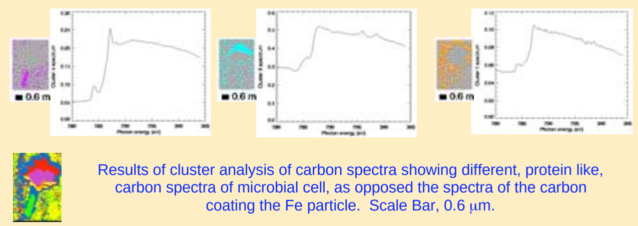
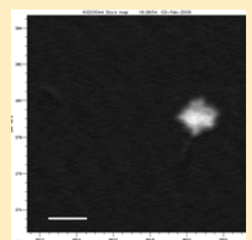


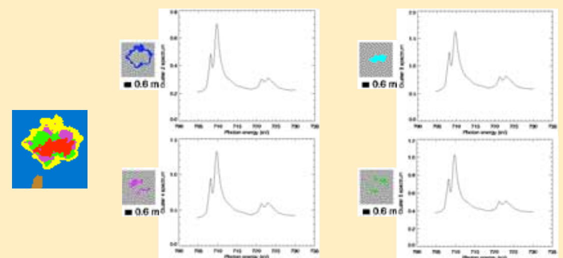
Carbon map showing microbial cells and Fe particle. Scale Bar, 2 μm.



Results of cluster analysis of carbon spectra showing different, protein like, carbon spectra of microbial cell, as opposed the spectra of the carbon coating the Fe particle. Scale Bar, 0.6 μm.



Iron map showing just the Fe particle and no cells. Scale Bar, 2 μm.



Results of cluster analysis of Fe spectra showing very little difference between regions of the Fe particle and the lack of any Fe coating on the cell. Scale Bar, 0.6 μm.

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